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Field Evaluation of Aerially Applied *Bacillus thuringiensis* (Berliner) Against the Browntail Moth, *Nygmia phaeorrhoea* (Donov)

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Field Evaluation of Aerially Applied *Bacillus thuringienses* (Berliner) Against the Browntail Moth, *Nygmia phaeorrhoea* (Donov).

by

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The browntail moth, *Nygmia phaeorrhoea* (Donov), was discovered in Somerville, Mass., in 1897. It was imported from Europe, probably on nursery or florists' stock (Burgess-Crossman, 1929). Thereafter, the insect spread along the Atlantic coast from Nantucket, Mass., to Eastport, Maine, and St. John, New Brunswick (Burgess-Crossman, 1929). Its westerly thrust extended into western New Hampshire and Vermont.

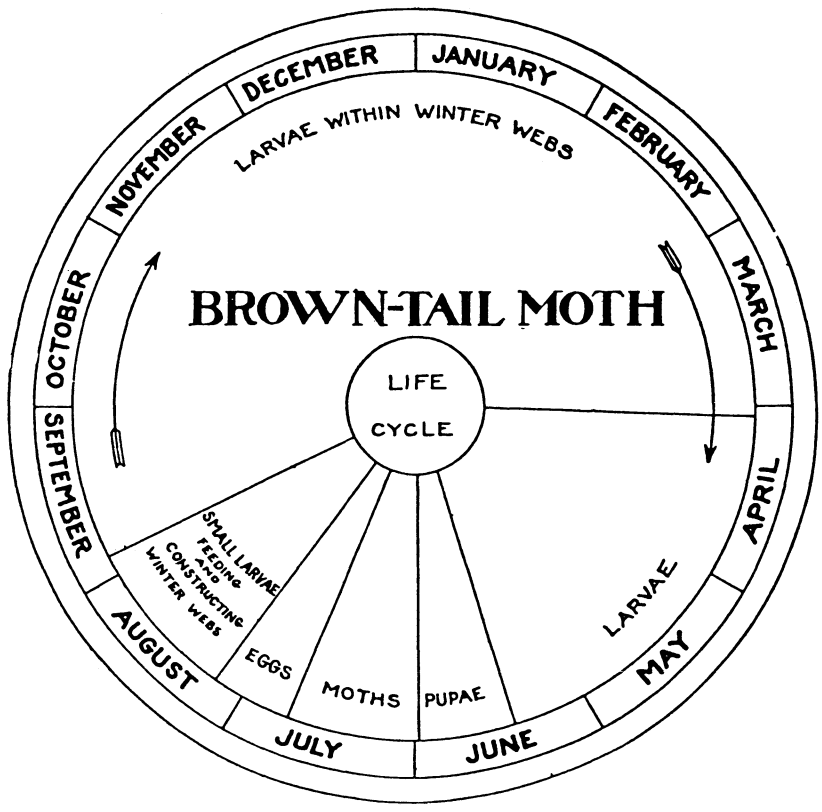

Figure 1.–Life cycle of the browntail moth (from Burgess and Crossman, 1929).

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Eggs of the browntail moth are usually laid during late July on the underside of leaves. Egg clusters are about 1.25 centimeters wide and 1.66 centimeters long and contain approximately 300 eggs. Eggs hatch during August and the small larvae feed on the upper leaf surface. After molting, larvae construct a hibernation web (7.5-15 centimeters long) from several terminal leaves drawn and fastened to the branch with a silk-like material. Webs are normally found very near hatched egg masses.

Overwintering larvae exit from the web on warm days in early spring. Larvae often return to the web as cooler evening temperatures dominate. Some of the major food plants of the browntail moth larvae are apple, pear, plum, oak, willow, and wild cherry (Burgess-Crossman, 1929). Larval development is complete by mid-June. Fifth-instar larvae are approximately 5 centimeters long and have a general brown appearance with broken white lateral stripes. A conspicuous orange-red tuberole is located dorsally on each of the sixth and seventh abdominal segments.

Larvae pupate in loosely woven cocoons, singly or clustered on leaves, trunks, or undersides of branches. The pupae are dark brown and about 1.6 centimeters long. Adults emerge about 2 weeks after pupation, usually during early July.

Adult moths are white except for the dark-colored tip of the abdomen. The abdomen is thickly studded with brown hairs and is slender on the male. The female's abdomen is much stouter. Adult moths of both sexes are strong flyers and are attracted to blacklight traps. Female flight normally is greatest during the first hour after sunset (Schaefer, 1974).

Over the past two decades the browntail moth infestation in the United States has declined noticeably because of efficient State and Federal scouting surveys, coupled with clipping and destruction of winter webs, and the use of chemical control. Also, adult insects do not have a propensity to migrate, which results in rather localized infestations.

The only presently known infestations in the United States are found along the coastal areas of Maine, adjacent islands in Casco Bay, and 5,400 hectares on Cape Code, Mass. The U.S. Department of Agriculture is presently attempting to eradicate the browntail moth from Maine and the coastal islands by clipping and burning winter webs and selective ground treatment with carbaryl. A similar eradication program by the U.S. Department of Agriculture has been proposed for Cape Cod, Mass. Aerial treatment will be necessary for effective coverage of the large, heavily infested areas on Cape Cod.

Approximately 70-75 percent of the Cape Cod infestation is on the Cape Cod National Seashore. U.S. Department of Interior policy discourages the use of chemical insecticides on National Seashore lands. Therefore, it was proposed that *Bacillus thuringiensis (Bt)* be tested against browntail larvae in the laboratory. If laboratory tests demonstrated the material was effective against the larvae, experimental field plots would be established to determine field efficacy for subsequent control operations.

Bacillus thuringiensis is a spore-forming bacterium which occurs widely in nature. The material is relatively selective as it exerts its lethal effect when alkaline conditions prevail in the gut of a host insect. The midgut environment of most lepidoptera meet this criterion while the pH of gut fluids in other forms of animal and insect life is neutral to acid. The active ingredient in *Bt* is produced by fermentation, utilizing equipment, technology, and quality-control standards comparable to those used in the production of antibiotics (Abbott Laboratories, 1972).

MATERIALS AND METHODS

Hibernating webs were collected during April from prospective spray plots on Cape Cod, taken to the laboratory, and held at 26°-27°C and 50 percent RH. When larvae emerged, they were transferred to petri dishes containing artificial diet (Leonard-Doane, 1966). A laboratory low-volume spray device was used for applying Dipel® flowable and Thuricide 16B®, both commercial preparations of *Bt*, to tender oak seedlings (Merriam, 1967). Twenty second-instar browntail moth larvae were introduced onto each of the treated plants (McLane, 1973). Each treatment was replicated five times. Five untreated plants served as controls. Mortality was recorded at 24-hour intervals.

Six 4-hectare spray plots on Sandy Neck in the town of Barnstable, Mass., and two plots of 12 hectares each on the National Seashore at Truro, Mass., were established. Two additional plots at each site served as controls. Each plot contained one evaluation site (subplot) per 2 hectares. Beach plum and *Rosa rugosa* were predominant host species. Criteria for plot selection areas were: (1) presence of a healthy browntail moth population, (2) population density of at least 25 webs per hectare, (3) site accessible by a four-wheel-drive vehicle, (4) area above high tidewater mark, and (5) isolation from dwellings.

All plots were sprayed on May 21, 1974, from a Piper Pawnee® aircraft equipped with a propeller-driven impeller pump and a conventional spray system. The airplane dispersed the material in 23-meter swaths at 160 km/hour, 12 to 15 meters above the foliage, with a ground wind velocity of less than 8 km/hour. Type 8008 flat fan nozzles with 25-mesh screens at 7 kg/cm were used, with nozzles pointing 90° to slipstream. All mixing was done in the aircraft spray tank.

Although weather conditions were optimum, beach plum and *Rosa rugosa* foliage were only expanded about 20 percent to 60 percent respectively. Application was conducted at this time because of the availability of the aircraft and the rapid development of the larvae. Conditions would have been more favorable if all foliage was extended 80 percent and larvae were predominantly second instar. Insects in test plots were second and third instar at the time of treatment.

A late treatment was similarly applied at Truro on August 21, 1974, in anticipation that newly hatched larvae would feed for a sufficient amount of time to ingest a lethal amount of *Bt.* Although complete hatch had occurred only 7-10 days prior to treatment, most larvae had already constructed a protective winter web around themselves at time of treatment. Foliage expansion was 100 percent and larvae were first instar. Wind velocity was 8 to 10 km/hour and good coverage was accomplished.

The May 21 treatments were evaluated by general observations and pre- and posttreatment terminal counts (three terminals per observation site) at 48-hour intervals. The August 21 treatments at Truro were evaluated by periodically observing larval activity in 12 selected overwintering webs for 14 days after spray application.

RESULTS AND DISCUSSION

Results of laboratory tests comparing the effectiveness of two formulations of *Bt* against second- instar browntail moth larvae are tabulated in table 1.

Table 1.—Mortality of second-instar browntail moth larvae exposed to oak seedlings treated with Dipel and Thuricide 16B

Formulation	Dosage BIU[1]	Rain	Percent mortality hours after treatment				
			24	48	72	96	120
Dipel	8	–	9	62	71	90	96
Dipel	8	–	25	73	93	100	–
Dipel	8	1.25 cm[2]	24	54	71	99	100
Dipel	4	–	4	58	69	79	93
Dipel	2	–	3	32	63	91	100
Dipel	1	–	0	7	23	52	93
Thuricide	8	–	18	48	68	100	–
Thuricide	8	1.25 cm	3	22	32	92	100
Thuricide	2	–	1	24	44	87	98
Thuricide	1	–	0	6	22	43	85
Control	–	–	0	0	0	0	0

[1] Billion International Units of potency per pound.
[2] Plants were exposed to 1.25 cm of artificial rainfall 2 hours after treatment.

Browntail moth larvae were shown to be susceptible to both formulations of *Bt* at dosages of 1-8 BIU. Since the data are somewhat difficult to relate to dosage, 8 BIU was arbitrarily chosen for field testing.

Results of efficacy tests of two formulations of *Bt* are presented in tables 2 and 3.

Table 2.—Browntail moth larvae population counts in plots treated with Dipel and Thuricide 16B and untreated controls. Sandy Neck test, May 1974

Material	Dosage BIU	Plot	Pre-spray	Terminal counts[1] hours after treatment		
				48	96	144
Dipel	8	1	8.5	8.5	13.5	14.0
Dipel	8	3	10.5	6.0	10.0	14.0
Dipel	8	5	7.5	20.5	17.5	10.0
Treatment average	–	–	8.8	11.7	13.7	12.7
Percent of pre-spray count	–	–	100.0	133.0	156.0	144.0
Thuricide	8	2	16.5	9.0	18.0	6.5
Thuricide	8	4	21.5	29.0	30.5	24.0
Thuricide	8	6	22.0	10.0	5.0	8.5
Treatment Average	–	–	20.0	16.0	17.8	13.0
Percent of pre-spray count	–	–	100.0	80.0	89.0	65.0
Control	–	1	7.0	12.0	10.0	18.5
Control	–	2	4.0	8.5	10.0	10.5
Control average	–	–	5.5	10.3	10.0	14.5
Percent of pre-spray count	–	–	100.0	187.0	182.0	264.0

[1] Each figure is the average of 6 terminal counts.

Table 3.—Browntail moth larvae population counts in plots treated with Dipel and Thuricide 16B and untreated controls. Truro test, May 1974

Material	Dosage BIU	Plot	Pre-spray	Terminal counts[1] hours after treatment	
				96	144
Dipel	8	1	24.6	20.2	13.7
Percent of pre-spray count	–	–	100.0	82.1	55.7
Thuricide	8	2	32.2	13.0	37.7
Percent of pre-spray count	–	–	100.0	40.0	117.0
Control	–	3	28.5	26.0	21.0
Control	–	4	10.5	35.0	22.0
Control average	–	–	19.5	30.5	21.5
Percent of pre-spray count	–	–	100.0	156.0	110.0

[1] Each figure is the average of 18 terminal counts in treated plots and 6 in control plots.

Browntail moth larvae terminal counts were reduced by treatment with Thuricide 16B at the Sandy Neck test sites. Population increased in both Dipel-treated and control plots. Conversely, Thuricide 16B yielded little or no mortality in the Truro test and, in this case, Dipel caused reduction of populations to 56 percent of pre-spray counts. In neither test did any formulation cause sufficient mortality to be judged efficacious.

At the time of the May treatment there was lack of suitable foliage. Also, the majority of larvae were in the third instar; laboratory tests were conducted with second- instar larvae. This could account for the inconsistency between laboratory and field experiments.

Although foliage was expanded completely at the time of the August treatment at Truro, results were poor. Little or no mortality was evident upon examination of larvae in overwintering webs. Little feeding takes place from the time eggs hatch to when small larvae construct winter webs. Additionally, most feeding occurs inside the web. Most larvae were already inside the winter web at the time of treatment. Leaf surfaces fed upon were protected from the spray droplets.

Data from some of the treatments demonstrated that even under less than satisfactory conditions some degree of control was achieved. It would seem likely that timing of treatment is the single most critical factor governing the potential success of utilizing *Bt* for control of the browntail moth larvae.

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